Proposed Approach for Including Basin Amplification in the 2018 NSHM's

Art Frankel

USGS, Seattle

2018 NSHM Update Workshop, March 8, 2018
Newark, CA

- This proposal is intended to start to address, in the NSHMs, the observations of long-period (1-10 s) amplification by deep basins in a consistent methodology for the Seattle-Tacoma, Los Angeles, and San Francisco Bay regions. Uses basin terms in NGA West 2.

- This proposal is for 2018 maps; I hope we include 3D simulation results in 2020 maps.

Proposal for Including Basin Amplification in 2018 NSHM's

- Consider only deep basins with Z2.5 ≥ 3.0 km, as determined from 3D velocity models based on seismological data (L.A., Seattle, S.F. Bay region) SLC has Z2.5 < 3.0 km; Campbell and Bozorgnia (2014) have amplification for Z2.5 ≥ 3.0 km
- Use Campbell and Bozorgnia (2014) basin amplification factors for all GMPEs for subduction zone earthquakes (interplate M8-9 and intraslab); assume that average Z2.5 for subduction zone datasets is the same as that for crustal earthquake database (hopefully NGA subduction database will help)

USGS
science for a changing world

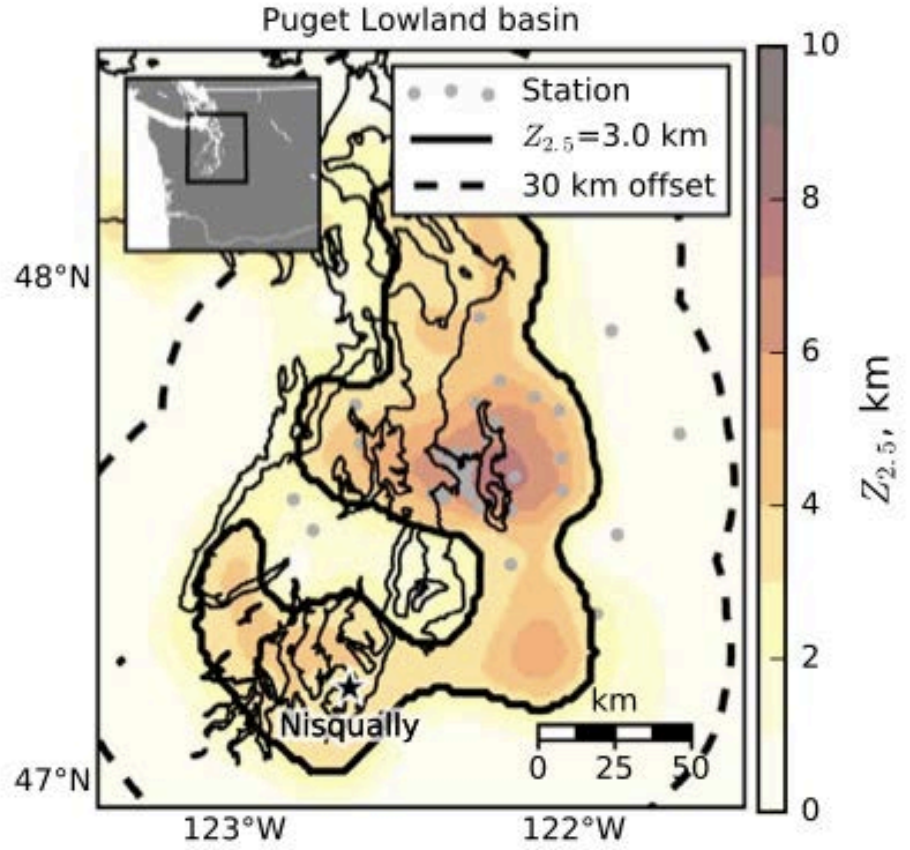
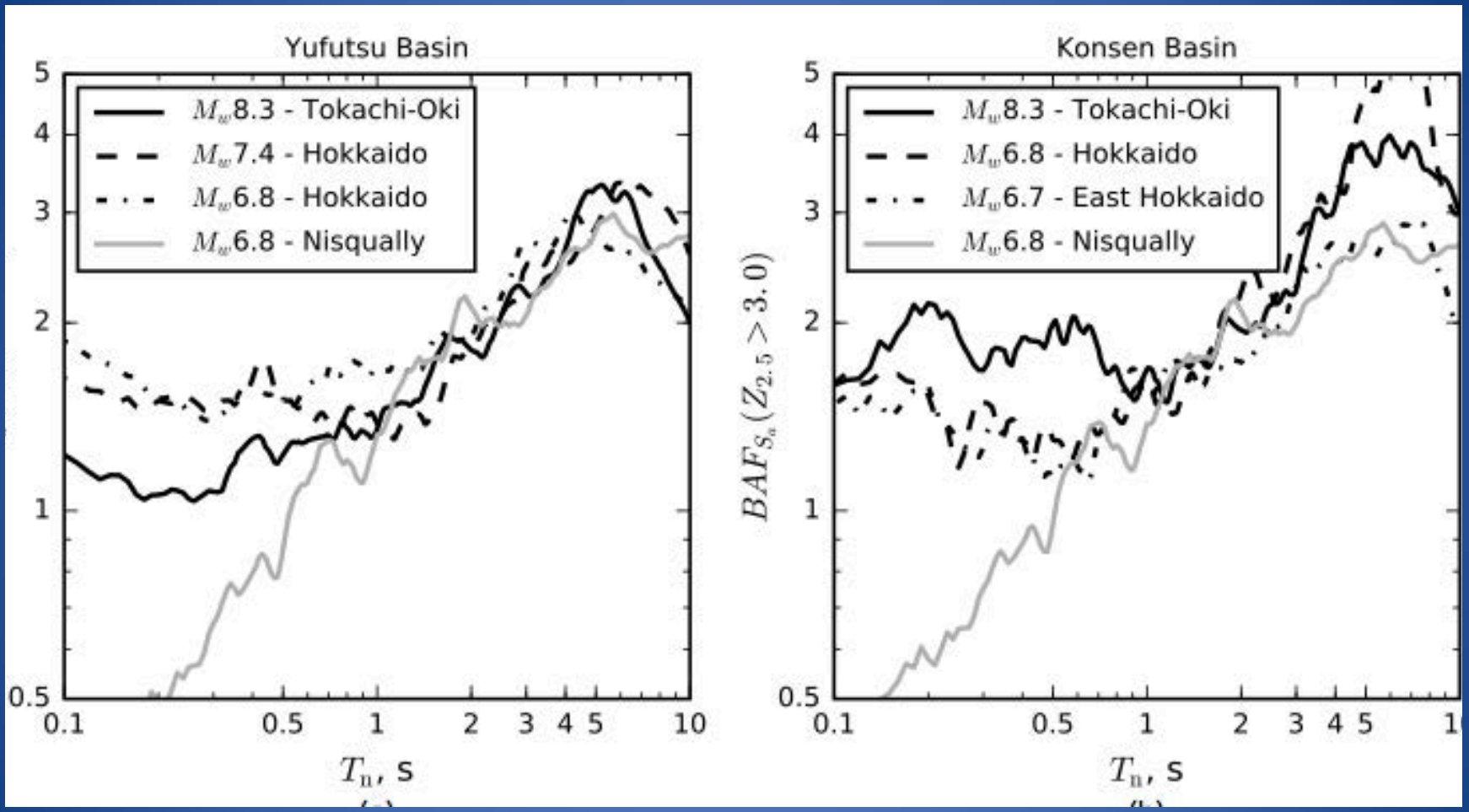


Figure 2. $Z_{2.5}$ contour map of the Puget Sound region.

Figure from Marafi et al. (2017; EQ Spectra)

USGS science for a changing world

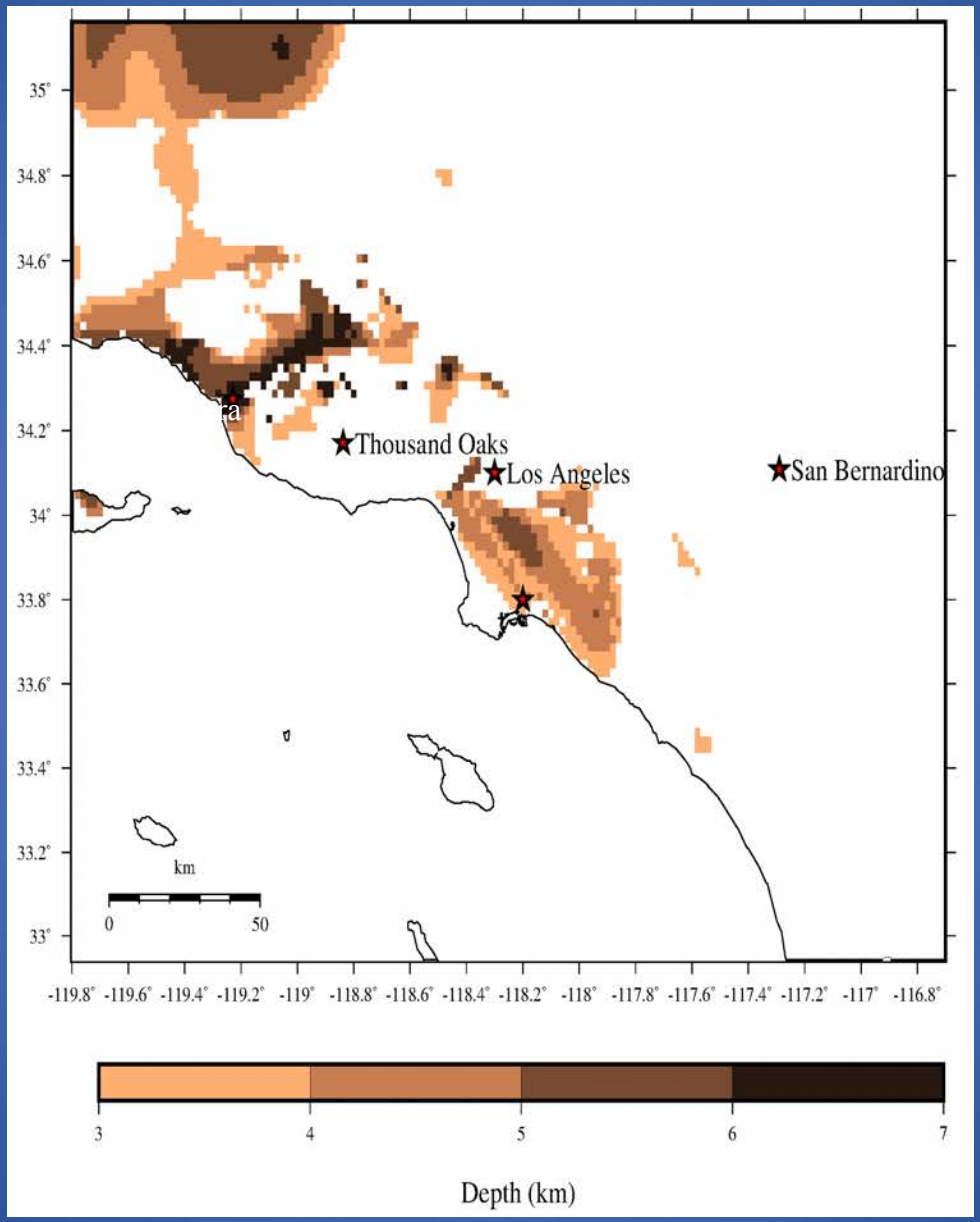
Observed amplification in Puget Lowland from Nisqually earthquake and basins in Japan from subduction zone earthquakes (Marafi et al. 2017)



Slide from Marafi et al. (2017, EQ Spectra)

Los Angeles Basin : Areas Where $Z_{2.5}$ > 3 km

Slide from
Allison Shumway

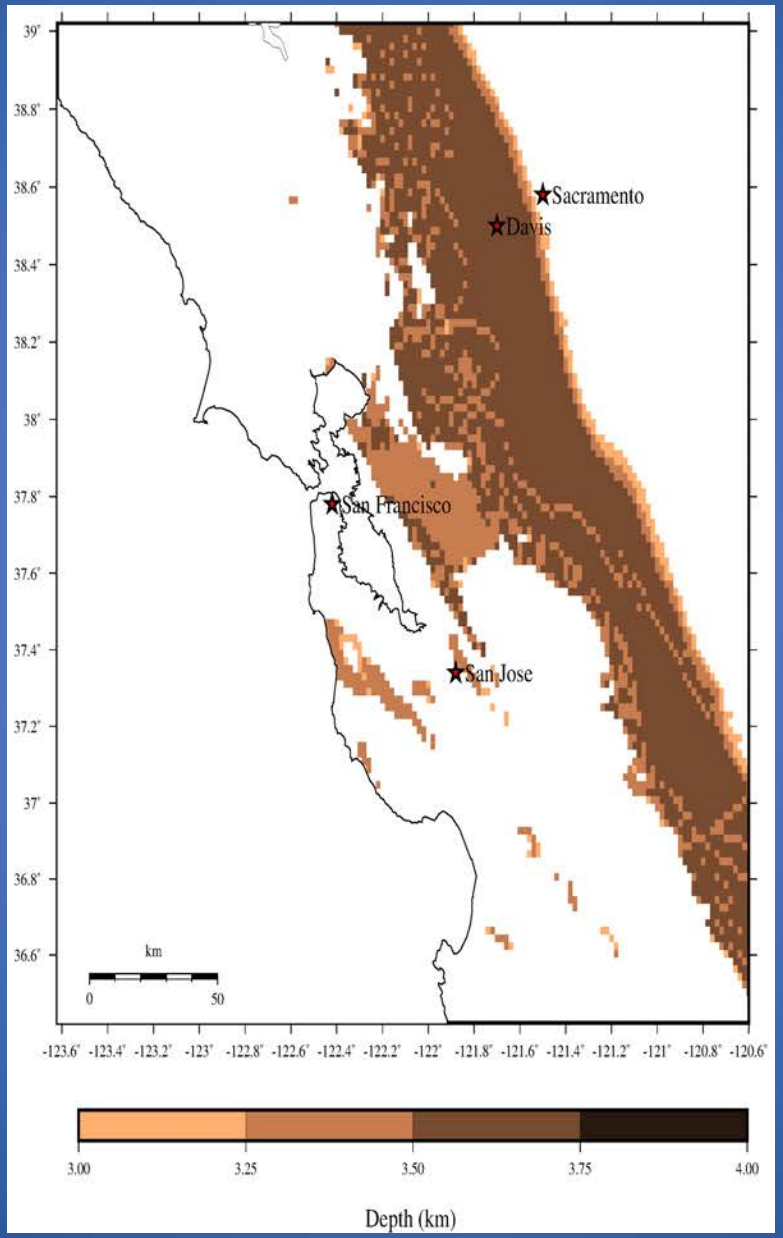


$Z_{2.5}$ values from local seismic velocity model: cvm S4.26m01 (Lee *et al.*, 2014)

USGS science for a changing world

Bay Area Basins: Areas Where $Z_{2.5}$ > 3 km

Slide from
Allison Shumway



$Z_{2.5}$ values from local seismic velocity model: BayArea10 (Aagaard *et al.*,2010)

USGS science for a changing world

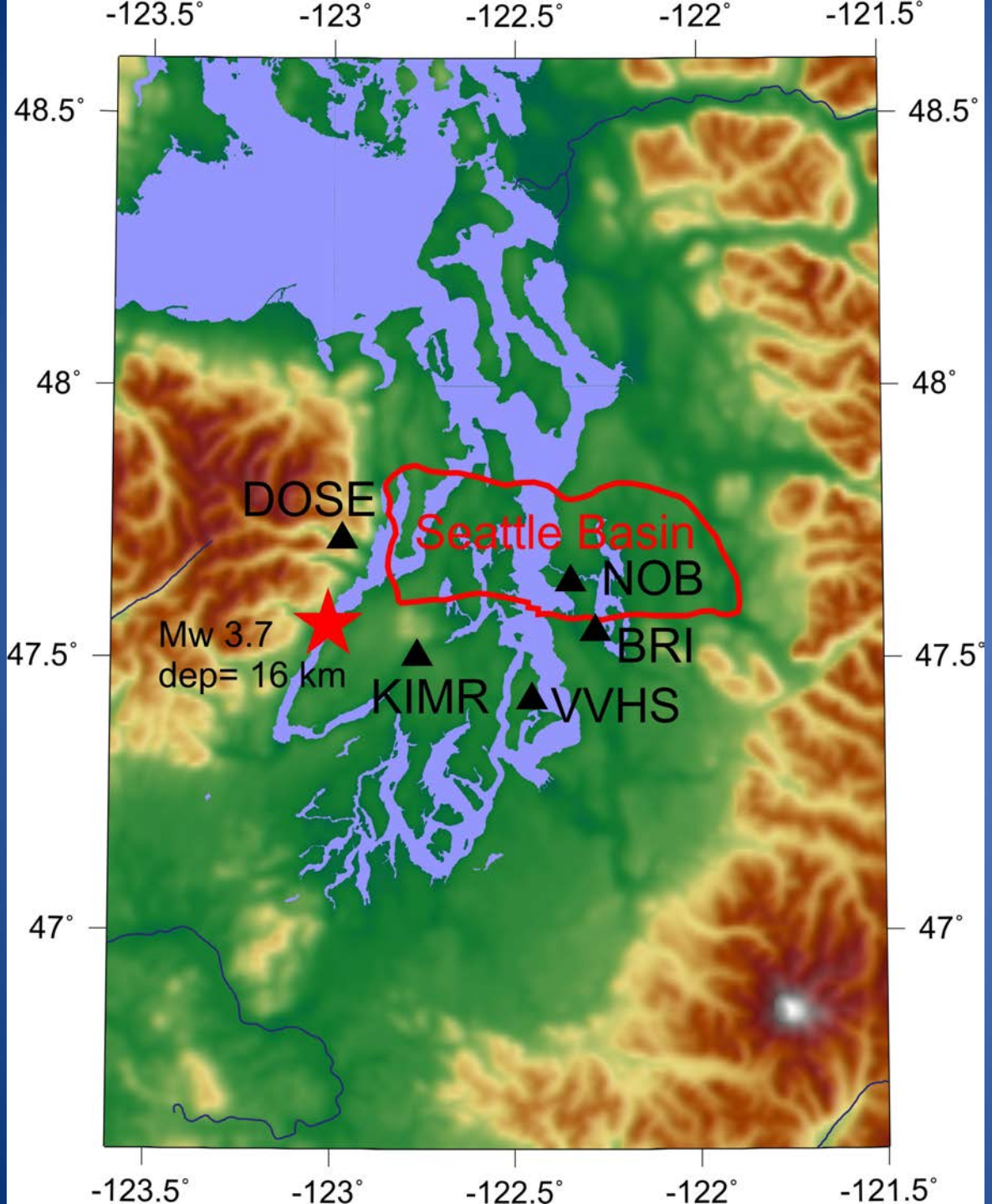
Basin amp factors for crustal earthquake GMPE's (NGA West 2) (only for sites with Z2.5 ≥ 3.0 km)

- For crustal earthquakes, use Z2.5 from 3D velocity models to get CB14 amplification factor. Three choices: (1) use CB14 factor for all other GMPEs for crustal earthquakes, or (2) convert Z2.5 to Z1.0 using formula in Campbell and Bozorgnia (2007) and then apply basin amp factors for Z1.0 in the other NGA West 2 GMPEs, or (3) use Z1.0 in 3D velocity models for these other GMPEs

USGS
science for a changing world

Why is Z2.5 preferred to Z1.0?

- In Seattle, near-surface glacial sediments (e.g., till) can have Vs of about 1.0 km/s with lower velocity below them.
- Areas with similar Z1.0 can have very different amplification. Compare sites on sedimentary rock just south of Seattle basin with rock site near Olympic mountains; sites near edge of Seattle basin can have high amplitudes, yet low Z1.0
- Z1.0 is poorly known in Seattle basin; largely interpolated from reflections found in marine surveys in Puget Sound and Lake Washington



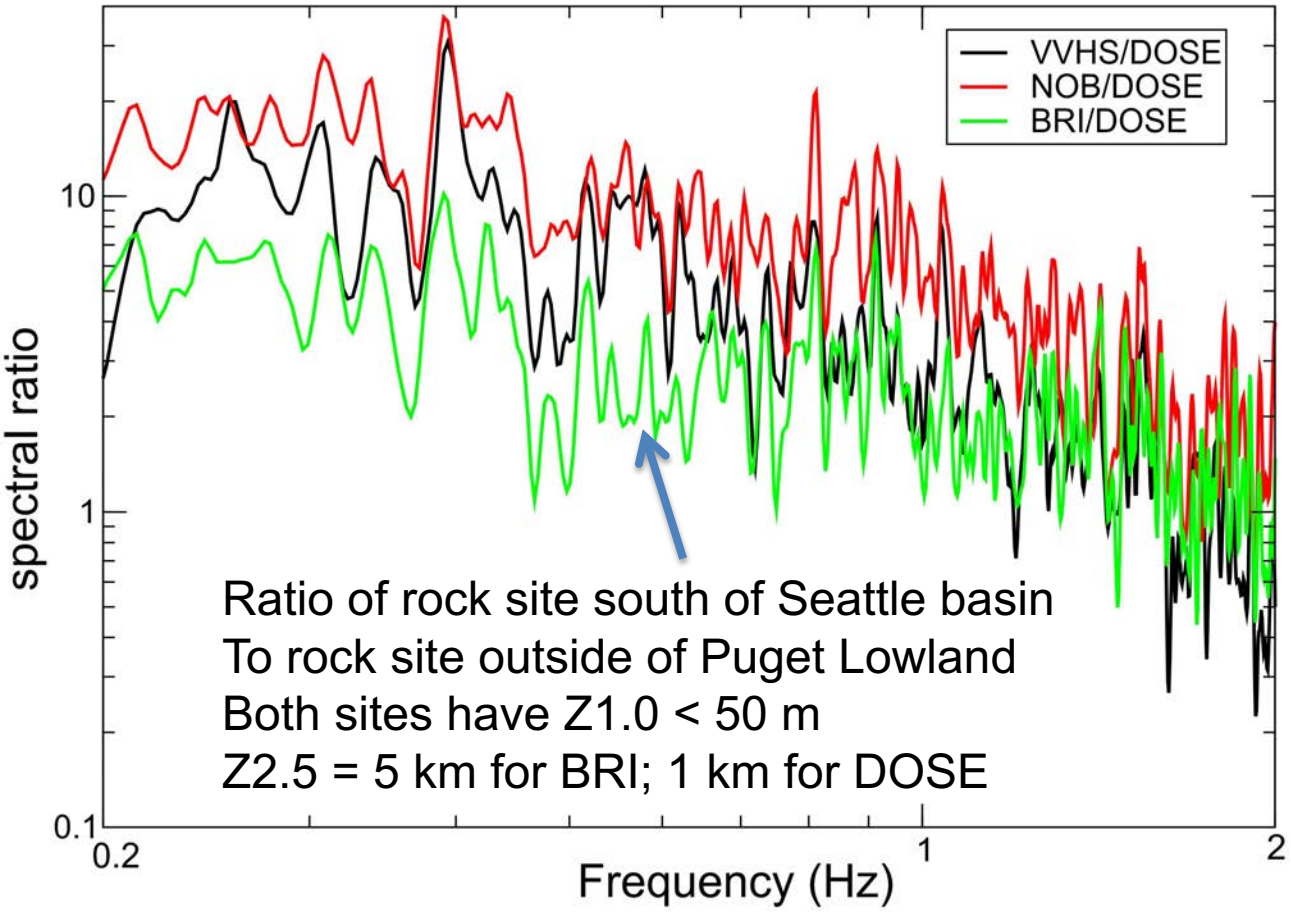
We determined Fourier spectral ratios for deep-soil sites with shallow soil site in the Puget Lowland (BRI) and rock site outside the Puget Lowland (DOSE)

BRI and DOSE have Similar Z1.0 less than 50m

DOSE Z2.5 = 1 km
BRI Z2.5 = 5 km

DOSE, KIMR, VVHS Are PNSN stations
NOB and BRI are USGS stations

USGS science for a changing world

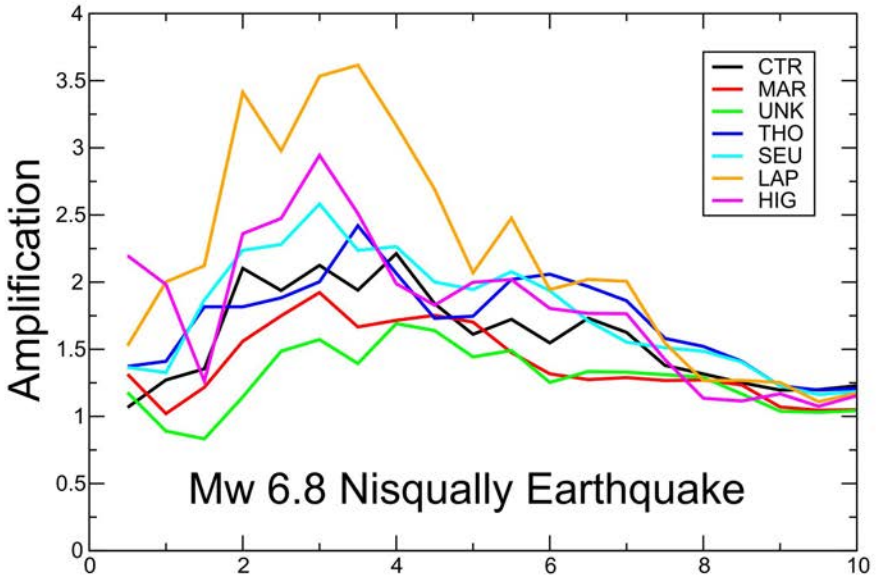


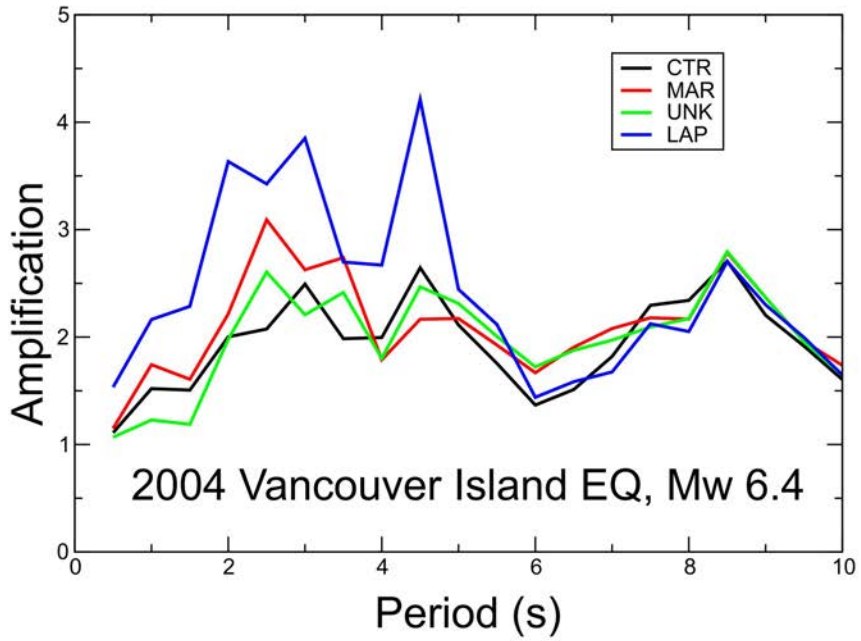
Fourier spectral ratios for recordings of M6.4 earthquake near northern part of Vancouver Island 9/9/2011

Note large Amplification at ≤ 1 Hz of deep soil sites (VVHS and NOB) & rock site (BRI) relative to rock Site DOSE outside Of Puget Lowland

Seattle basin site NOB has highest amplification ≤ 0.5 Hz

USGS science for a changing world





Observed amplification of spectral response values for stiff soil sites in the Seattle basin

Referenced to site with thin soil over firm-rock outside of basin

These sites have similar Vs30 Values.

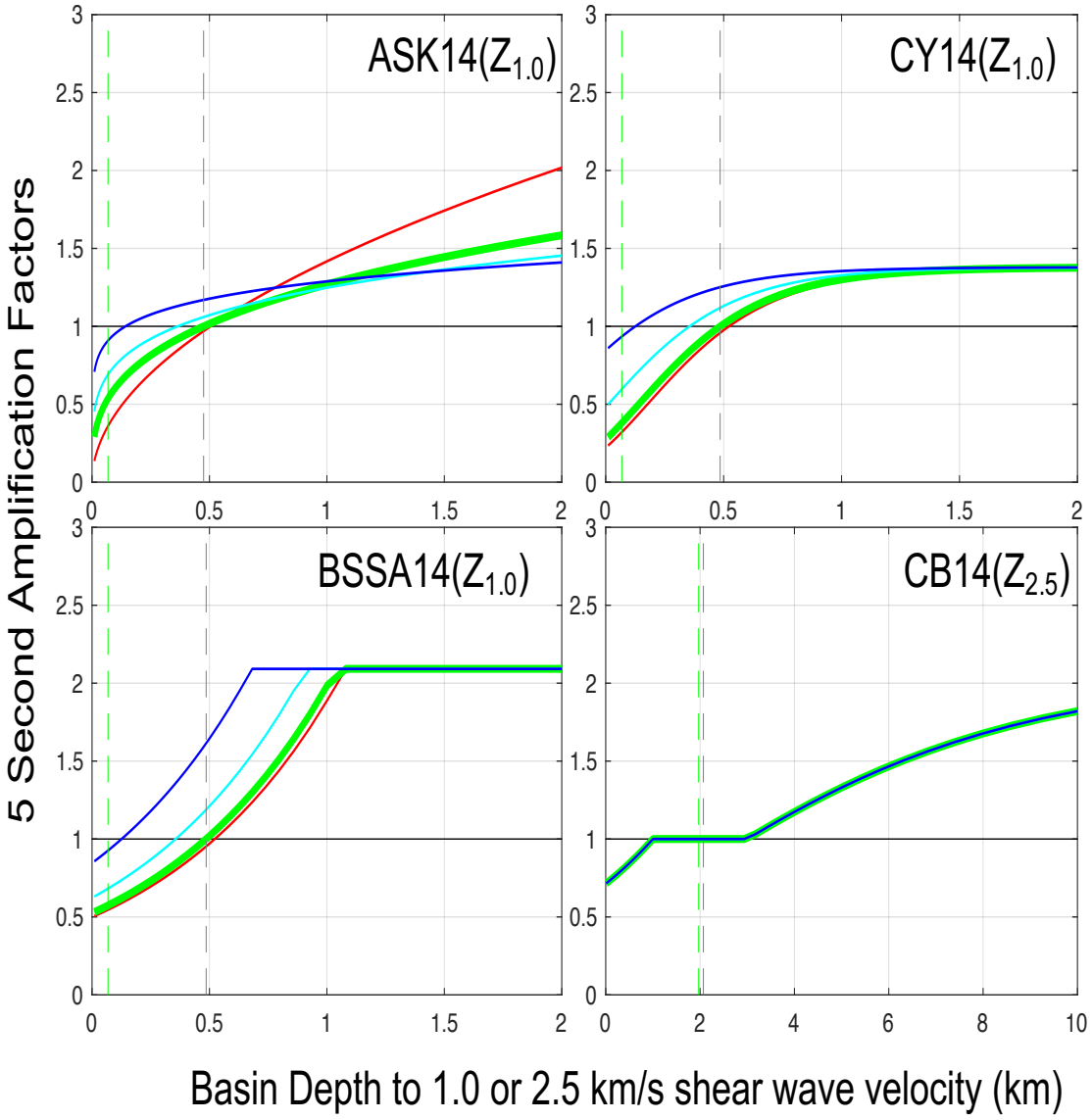
Note there is more Amplification when referenced to sites outside of Puget Lowland

USGS science for a changing world

Slide from Allison Shumway

Basin Depths

Default
V_{s30} =260 m/s
$Z_{1.0}$ (ASK14) = 0.475 km
$Z_{1.0}$ (BSSA14) = 0.486 km
$Z_{1.0}$ (CY14) = 0.485 km
$Z_{2.5}$ (CB15) = 2.07 km



Z2.5 3.0 km➔
Z1.0 0.7 km
CB07

USGS science for a changing world

Do not decrease ground motions relative to default for sites with Z2.5 < 1.0 km or Z1.0 < Zref

- Large uncertainty in Z2.5 determinations for Z2.5 < 1.0 km; steep Vs gradient; how was the shallow Vs determined in the 3D models? Possibility of resonances; Vp (and Vs) from earthquake tomography is better resolved at depths of 3-5 km than above 1 km.
- Boore and Joyner (1997) generic WUS rock-site Vs profile has Z2.5 of 1 km

USGS
science for a changing world

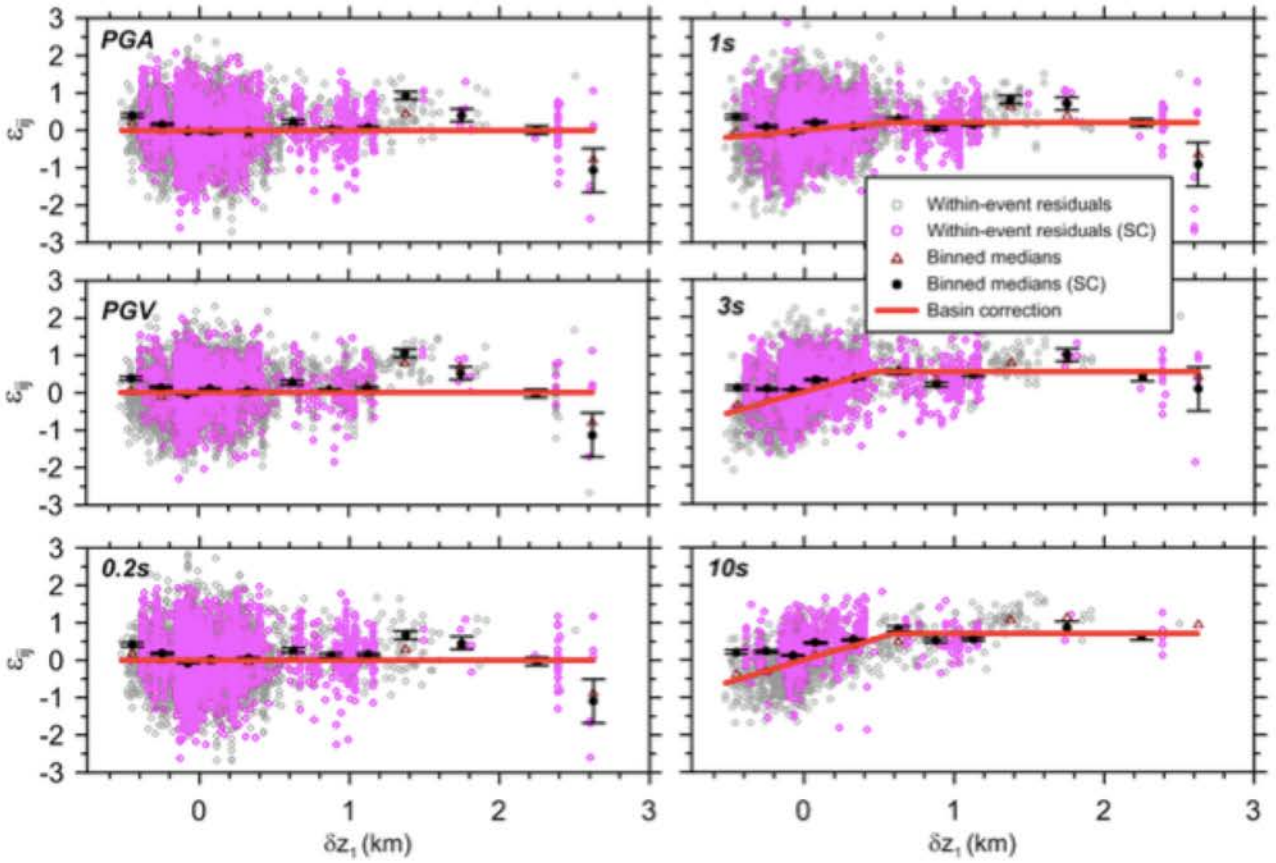


Figure 4.27d **Within event residuals against sediment depth differential δ_{z1}, highlighting SC sites. Non-SC sites shown with grey circles.**

Figure from Boore et al. (2013)

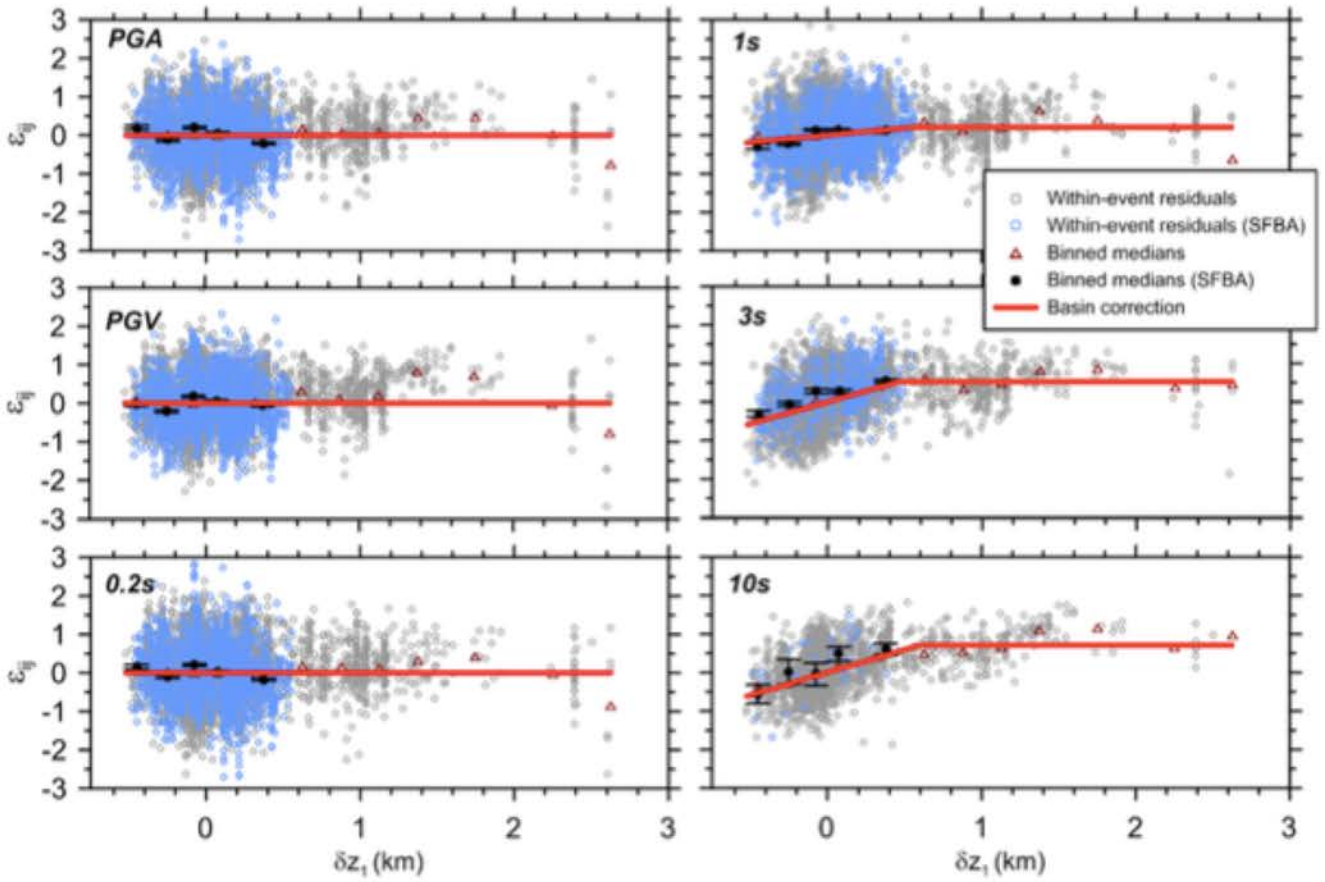


Figure 4.27b **Within event residuals against sediment depth differential δ_{z1}, highlighting SFBA sites. Non-SFBA sites shown with grey circles.**

Figure from Boore et al. (2013)

Conclusions from Chang, Frankel, and Weaver (2014) "Report on Workshop to Incorporate Basin Response in the Design of Tall Buildings in the Puget Sound Region, Washington" USGS OFR 2014-1196

- Recommended inclusion of basin amplification terms for tall buildings (> 20 stories) in Seattle
- Recommended use of Z2.5 from Stephenson (2007) model, since shallow glacial tills can have Vs ≥ 1.0 km/s with lower velocities below. Could convert Z2.5 to Z1.0 for use in GMPEs with Z1.0 (use equation in Campbell and Bozorgnia, 2007).

USGS science for a changing world

Summary of Proposed Approach for Including Basin Amplification in 2018 NSHM's

- Only consider areas with Z2.5 ≥ 3.0 km, from 3D velocity models based on seismological data
- Use CB14 basin amp factors for all subduction zone GMPEs
- Convert Z2.5 to Z1.0 (CB 2007) to get basin amp terms for other NGA West 2 GMPE's
- Do not consider ground motions less than the default values for the GMPE's, because of uncertainties in shallow Vs and possible velocity inversions with depth

USGS
science for a changing world